THE ELIMINATION OF VELOCITY EFFECTS IN MEASURING PRESSURES IN A FLUID STREAM.

By FRANCIS E. NIPHER.

(*Read April 20, 1906.*)

In determining either velocities or pressures in a current of air or water within a pipe, it has always been found exceedingly difficult to obtain a value which has any physical meaning.

A straight tube thrust through the side of the pipe, terminating at some point within, and connected to a guage, will transmit the pressure, but on account of the draught of the fluid across the open end of the tube, the fluid will also be drawn out, by an atomizer action.

If on the other hand the tube is in the form of a Pitot tube with its mouth directed towards the advancing current, it transmits both static and dynamic pressure to the gauge.

In the case of a building or other structure in a stream of air, if it is desired to find the variation of pressure on the surface due to the wind, any form of barometer gives misleading results by reason of the compressions and rarefactions around the instrument itself. Moreover the wind sweeps across or into various openings leading to the mercury surface or flexible diaphragm. This introduces disturbances or errors, which cannot be corrected. Engineers are accustomed to combine with the Pitot tube, a similar tube with its opening at right angles to the stream lines in a pipe, but they usually give warning that the atomizer action of the air blowing across the opening is likely to give misleading results, if the velocity is great.

In order to study the Pitot tube in a manner that would eliminate statical pressure, a long series of experiments was made from the window of a car. The tube was so mounted that the mouth of the tube could be directed at any angle, the position being determined on a graduated circle. The mouth of the tube could thus be directed towards the head of the train, towards the sky, the rear of the train, towards the ground and then towards the head of the train again. The setting could be made for each ten degrees. The zero angle was taken when the mouth of the tube was directed towards the head of the train, the pressure being then a maximum. The tube had a diameter of one inch, and the walls of the tube were of thin metal. For angles between 0 and 60°, the pressures were positive. At 60°, the pressure observed was zero. At an angle of 90°, the decrease in pressure was greater than the increase when the angle was zero.

The values observed are here given, the pressures being in grams per square centimeter. These values may, of course, be represented by an harmonic series. It requires about ten terms.

a	*P*	*a*	*P*
0	1.34		
10	1.30	100	—1.29
20	1.26	110	—1.03
30	1.21	120	—0.93
40	1.03	130	—0.89
50	0.63	140	—0.86
60	0.00	150	—0.86
70	—0.63	160	—0.79
80	—1.10	170	—0.66
90	—1.44	180	—0.54

These values are plotted in a polar diagram in Fig. 1.

The pressures were measured with a water manometer, having its tube inclined to a slope of one in twenty. The actual readings were, therefore, twenty times the numbers above given.

These values are the means of twenty measurements. The average velocity of the train as determined by simultaneous measurements with another Pitot tube was 41.8 miles per hour. The relative velocity of the air with respect to the train at the point where the measurements were made was 32.5 miles per hour. This lesser relative velocity was due to the fact that air was dragged along with the train.

It is therefore evident that in such a stream of air, a tube which is to eliminate the velocity effects, must be set with its mouth directed at an angle of 60° with the stream lines, and not at an angle of 90° as is the usual custom.

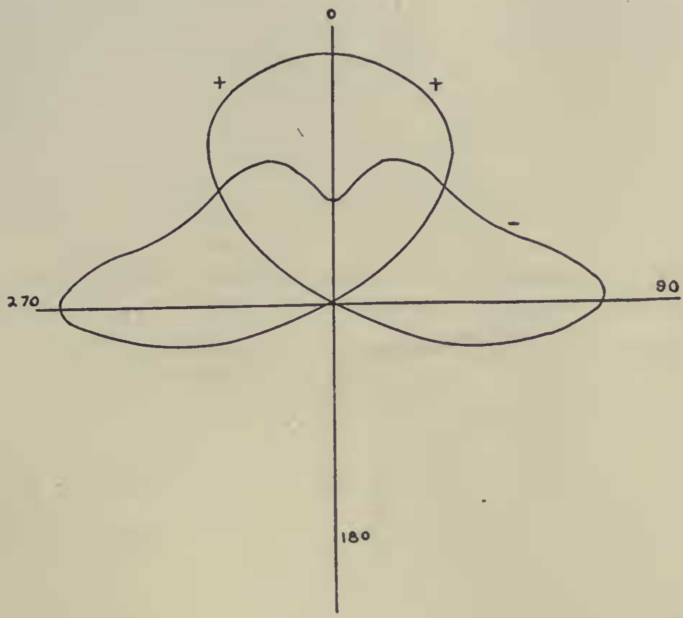

FIG. 1.

Two tubes rigidly connected and having their axes at an angle of 60° inserted into a pipe through which air is flowing will separate velocity pressure from staticial pressures. One is to be so turned in the stream that the reading of its gauge is a maximum. It will indicate both pressures. The other indicates only the actual pressure due to resistance of the pipe in advance of that point, if the discharge is into the air. Such statical pressure differences at two points along the pipe, will correspond to voltmeter readings between the points on a wire carrying an electric current.

Another means of eliminating velocity effects is given by a device which I here present.

A tube to carry the pressure to the gauge, terminates at the point where the pressure is to be collected, in a thin circular disk, placed edge-wise in the stream. A parallel disk is secured to it by soldered or brazed rivets, with four or five circular sheets of wire cloth loosely clamped between the disks. The bundle of wire cloth sheets projects to some distance beyond the metal disks. On either side of the disk-collector so formed, a couple of sheets of wire cloth are laid, thus hiding the metal disks in the wire-cloth bundle.

With this arrangement, the pressure at the mouth of the collecting tube is wholly unaffected by the motion of the current of air. The compression and rarefaction around the tube are prevented from affecting this pressure by the two disks. The compression and rarefactions around the edges of the wire cloth bundle are also eliminated by the projecting margin around the edges of the disks, so that these compression and rarefaction effects do not get between the disks. They do get between the disks and affect the reading in a way that cannot be corrected, if the wire cloth layer does not project beyond the metal disks.

The layers of wire cloth on the outside of the disks is a recent improvement, which is necessary for very high velocities. It serves to smooth away irregularities in outline and prevents rarefactions due to these irregularities in the projecting layer of wire cloth from affecting the air pressure between the disks.[1]

When this disk collector stands edge-wise in free air in a current of air from a ten inch pipe delivering 96 cubic feet per second, the gauge connected with it is not in the least affected.

For comparatively small velocities and uniform pressures, as in pipes connected with blowers, the tube piercing one disk of the collector may be very small for a distance of an inch, and then widen in order to give necessary stiffness. The wire cloth layer need not then be over an inch in diameter, and the metal disks need not be over half an inch in diameter.

In measuring wind pressures on buildings where the pressures vary rapidly the tube should be a quarter of an inch in diameter, and the disks should be three and one-half inches and the wire cloth layers from five to five and one-half inches in diameter. The disks are placed flatwise near the wall.

[1] *Trans. Acad. of Sc. of St. Louis,* VIII.: 1.

These disk collectors may also be used with perfect results in water pipes, if the velocity is not great enough to produce discontinuities where air would show rarefactions. No tests have yet been made under these conditions. For high velocities the action of the Pitot tube deserves a complete re-investigation. It seems probable that the tube inclined at an angle of 60° with a Pitot tube will be the best method of eliminating velocity effects in a current of water at very high velocity.

In measuring wind pressures on buildings by means of inclined water gauges, the open end of the tube must be connected with a large reservoir, which is connected to a horizontal disk collector, far above the building. The disk is to be horizontal, so that the air current strikes it edgewise. These disks are now being mounted on the physics building of Washington University. Nearly a mile of piping is being used in connecting the various collectors, each

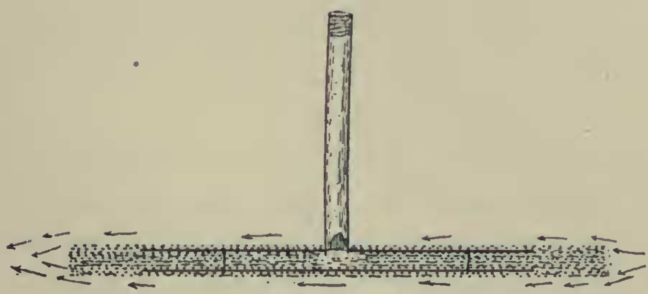

FIG. 2.

with its own gauge. The details of the collector are shown in Fig. 2, in cross section.

The two collectors here shown are presented to the society.